Bottom Hole Pressure Testing Results
WDW-410
Conroe, Texas

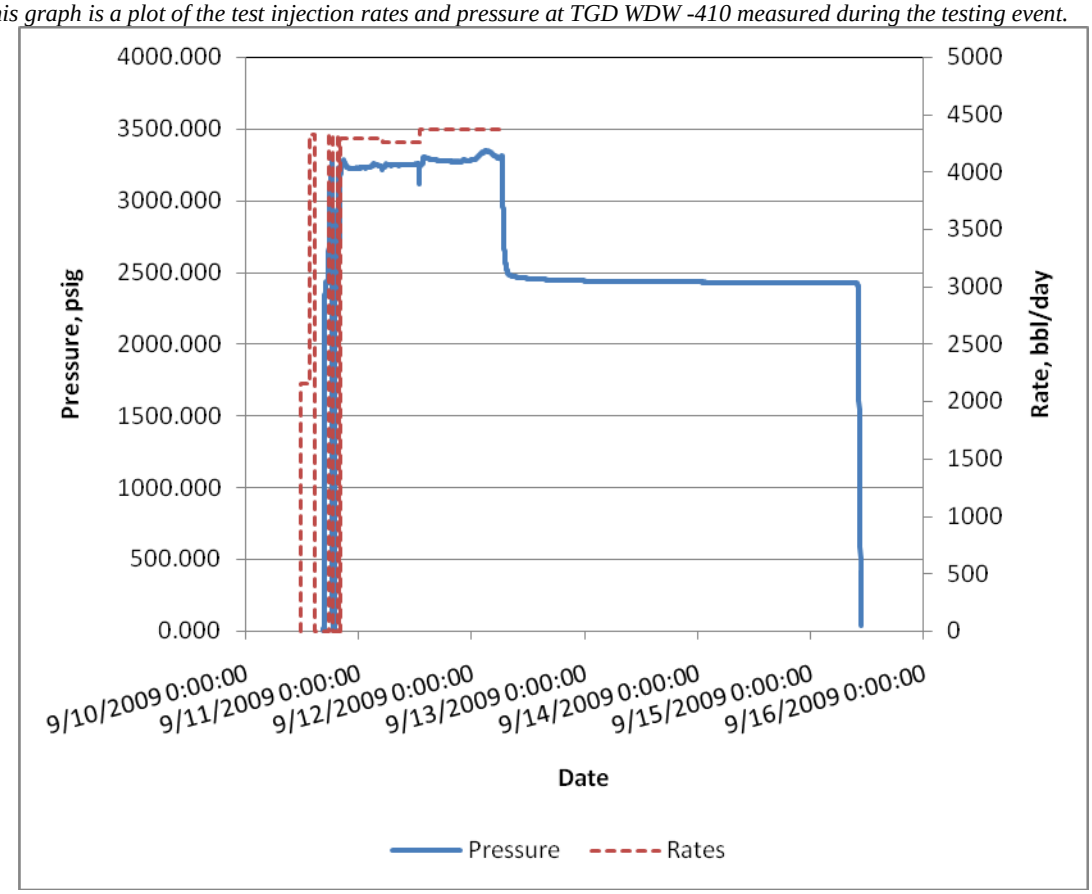
Background

This report presents the bottom hole pressure test pressure transient analyses (PTA) for the Texcom Gulf Disposal, LLC WDW-410 Injection Well conducted from September 10, 2009 through September 15, 2009. The test information was gathered and analyses performed in an effort to determine reservoir permeability after perforating additional intervals in the wellbore.

The purpose of this PTA is to present data and analytical results using standard petroleum and injection well methods to better define reservoir conditions at an injection site. Texcom Gulf Disposal (TGD) conducted the test of the well in September, 2009. The test on TGD's WDW-410 injection well was performed through the use of frac tanks located at the well. Fifteen frac tanks were positioned on site during the week and filled with brine. Just prior to performing the injection test on the well, additional perforations were placed in the wellbore and a Radioactive Tracer Survey was performed.

On the afternoon of September 10, 2009, Wood Group Logging ran in hole with a downhole memory pressure gauge connected to a surface readout pressure gauge. The pressure tools were positioned in the well at 6,000 ft. Beginning at approximately 5:40 pm on September 10, 2009, injection was initiated into the well to conduct the injection portion of the test. The injection portion of the test was started on the evening of the 10th and lasted for approximately 37 hours with shut in beginning at approximately 6:40 am on September 12th, 2009. The well remained shut in for approximately 75 hours. The BHP tools were pulled from the well on the morning of September 15, 2009. Figure 1 is a Cartesian plot of the injection rates and pressures monitored during the test. The pressure monitoring of the test was monitored at approximately 15-second intervals by the pressure probe. The raw data from the probe is included on the data disk with this report.

Figure 1
Injection Rate and Pressure vs Time Plot
This graph is a plot of the test injection rates and pressure at TGD WDW -410 measured during the testing event.



Pressure Transient Analysis Theory

During a PTA, test results are derived from what is termed the "transient flow regime." During this flow regime, the pressure response to the wellbore from the surrounding reservoir formation acts as if the reservoir is infinite. That is, only the effect of the surrounding rock matrix is felt at the wellbore and the pressure wave caused by a change in injection rate or the stoppage of injection has not encountered a so called "boundary" effect. The pressure waves can be envisioned like the rings caused when a rock is tossed into a pool of water. When the waves encounter the shore or even other waves in the pool the end of transient flow has occurred. It should also be noted that in pressure transient testing, a boundary effect is not necessarily a physical boundary of the reservoir rock. Besides the physical ending of the reservoir formation, a boundary effect can be caused by other wells, a recharge aquifer, sealed or leaky faults, and even a significant change in the reservoir flow characteristics. In this report, a detailed theoretical background on the PTA performed is not presented. Details on PTA can be found in many sources in literature.

Data Preparation

In PTA, accurate production/injection data, reservoir fluid properties, and reservoir formation characteristics is a necessity. This data has been gathered from many sources including the test event, by well construction, and by standard correlations. The original reservoir conditions of this property are presented in the injection system permit application. The following glossary of reservoir properties was characterized for this test:

Viscosity**:** Viscosity is a measure of a fluid's resistance to flow and is measured in the units of centipoise. For this test, the viscosity has been based upon a correlation[1] that takes into account fluid and injection temperature and the injectate's specific gravity.

Formation Volume Factor: A formation volume factor represents the change in volume of a fluid measured at reservoir conditions (pressure and temperature) vs. surface conditions and is measured in the units of reservoir volume divided by surface volume. This value was assumed to be unity as the volume of dissolved gases in the injectate and the changes in volume due to pressure and temperature changes is negligible.

Radius of Wellbore: The wellbore radius represents the physical dimension of the drilled hole through the injection interval and is in inches. Values for wellbore radius were derived from well diagrams present in the injection system permit application.

Injection Interval Thickness**:** Injection interval thickness represents the height of the formation that is available to receive fluid during the injection process.

Porosity: Porosity is a measure of the void space percentage of the reservoir rock matrix. This value was derived from the injection system permit application.

Total Compressibility: Total compressibility represents the change in volume of the total system (fluid and rock matrix) to a change in pressure and has the units of "/psig". This value was derived from the correlations[2,3,4] for sandstone and water.

Flowing Pressure: This pressure (psig) value represents the pressure at the end of the injection period, immediately before the fall-off period is initiated. These values were measured during each test.

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[1] Matthews, C.S. and Russell, D.G., "Pressure Buildup and Flow Tests in Wells, Monograph 1", SPE of AIME, Henry L. Doherty Series, Dallas, 1967.

[2] Earlougher, R.C., Jr., "Advances in Well Test Analysis; Monograph 5", SPE of AIME, Henry L. Doherty Series, Dallas, 1977.

[3] Koederitz, L.F., "Notes on Well Test Analysis", University of Missouri-Rolla, Rolla, MO, December 1990.

[4] Lee, John, "Well Testing", SPE of AIME, SPE Textbook Series Vol. 1., Dallas, 1982.

Injection Rate**:** The injection rate (volume/time) is a measure of the amount of fluid injected into the well over the time period prior to shut-in. Injection rates were measured onsite for the test.

Pressure-Time Pairs: The pressure-time data pairs were downloaded from a pressure probe. During analysis they were formatted to represent a delta time (hours) from the start of the testing event and the number of points was reduced to fit the data requirements of the analysis software.

The above definitions are presented to give the reader a background in the data utilized during a pressure transient analysis. They are not intended as a complete data dictionary for pressure transient testing. A complete data dictionary of pressure transient analysis testing would go far beyond the scope of this work.

Analysis of the Test

The following section details the analysis performed on the September 2009 testing event. The data presented below was used during the analysis of the pressure-time data points. Also presented are the analysis plots generated during the evaluation of the test. A summary of the test results follows this section.

The following figures present the test properties used in the analysis of the data. Figure 2 is the reservoir and test properties and Figure 3 is the injection rate data.

FIGURE 2

Reservoir and Test Properties

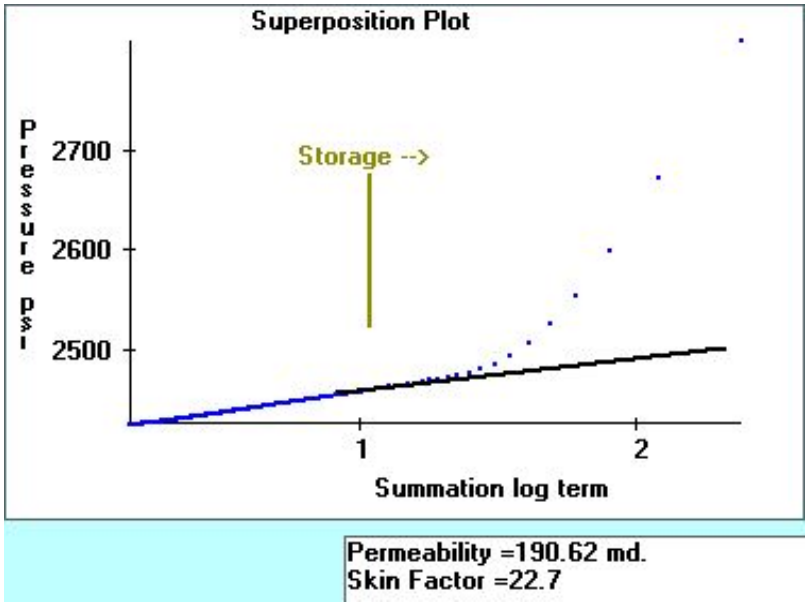
Property	Value	Source
Viscosity of injected fluid, μ	1.26 cp	Derived from correlations based on temperature, pressure and Specific Gravity of injectate
Temperature	97.6º F	Measured
Specific Gravity of injectate	1.18	Measured, 9.9 ppg brine
Formation Volume Factor, B	1.00 RB/STB	Assumed due to conditions
Net Pay, Injection Interval Thickness, h	145 ft	Determined from perforations
Radius of Wellbore, r_w	3.5 in	From well construction
Porosity of Formation, ϕ	24 %	From Permit Application
Total Compressibility, c_t	6.0×10^{-6} psi^{-1}	From Correlations
Pressure at beginning of Well Injection, p_i	2437.2 psig	Measured during test @ 6,000’
Pressure at beginning of Well Shut In, p_{ws} (p_{wf})	3306.2 psig	Measured during test @ 6,000’

Figure 3
Injection Rate Table
The following injection rates and durations were used during the analysis of the Falloff PTA.

Rate (STB/day)	Duration (hrs)
0.0	24.0
2160.0	2.0
4320.0	1.0
0.0	3.0
4320.0	0.69
0.0	1.15
4320.0	0.31
0.0	0.18
4291.2	8.95
4262.4	8.05
4369.0	17.64

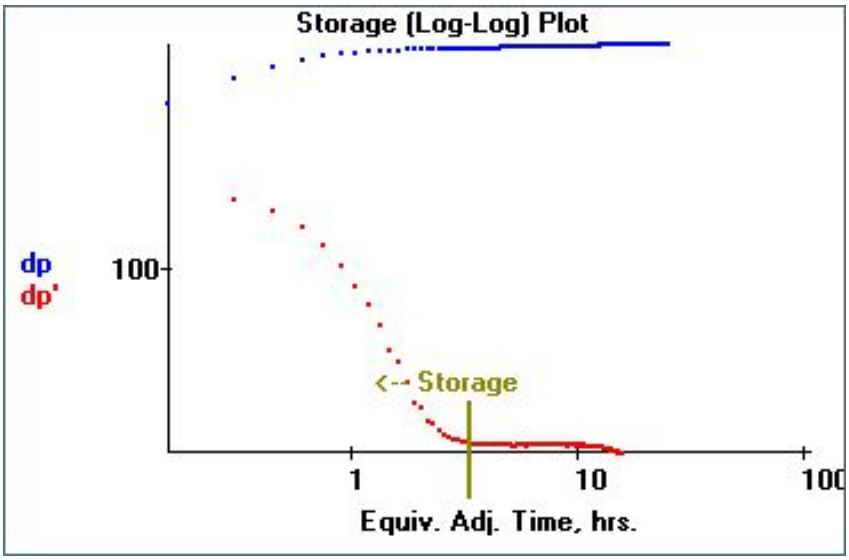
Pressure transient analysis techniques were performed using the data presented above and the pressure-time pairs downloaded from the pressure probe installed in the well. The data files were utilized in the program "Graphical Well Test Analysis", to perform the pressure transient analysis. The superposition (semi-log analysis) technique was used to analyze the injection falloff data. A screen capture from the well test program of the superposition (semi-log) analysis technique performed is presented in Figure 4. The superposition fall-off pressure transient analysis was performed due to measured varying injection rates prior to the falloff portion of the test. A permeability of 190.6 md was calculated for the well during the transient flow regime of the test. The well showed a positive skin factor which indicates that there may be a restriction of flow exiting in the wellbore or immediately surrounding the wellbore.

FIGURE 4
Superposition Analysis Plot
Analysis plot showing a superposition (semi-log) straight-line analysis on the transient flow regime.



Additionally the screen capture of the storage plot (Figure 5) presents information on the flow regimes encountered during the test. The early portion of the storage plot is believed to show a storage pressure response for the injection interval and wellbore as it comes to equilibrium. There appears to be a transient flow regime following the storage. This transient flow regime provides the analyzable data.

FIGURE 5
Storage Plot
Storage (Log-log) Plot showing flow regime characteristics



Radius of Investigation

One purpose of the testing was to attempt to determine if the fault located to the south of the injection well is closed or open to flow. After completion of the test a radius of investigation analytical calculation was performed based on the above data and analysis and the following equation[2]:

$$r_d = 0.029\sqrt{\frac{kt}{\varphi\mu c_t}}$$

Where:

r_d=	Radius of Distance	φ=	Porosity, fraction
k =	Permeability, md	μ=	Viscosity, cp
t=	Test time in hours	c_t=	Total Compressibility, 1/psi

Using the falloff test time of 75.5 hours yields a radius of investigation of approximately 2,583 ft. This is less than hoped for and is due to the permeability being lower than expected along with well bore or near well formational issues

such as cement contamination of the near formation, plugging of the well perforations from cement, well fines brought to the well during the clean out operations, or fines clogging the flow paths within the formation which are all factors that are indicated by the high skin factor.

Conclusions

The results of the PTA testing give an indication of the current reservoir conditions of the injection interval. A pressure transient response was seen at the wellbore and was able to be analyzed yielding an injection interval permeability of 190.6 md. This permeability is lower than expected in relation to the core analysis work skin indicates that there may be some restrictions to flow occurring near wellbore. The results are higher than shown previously in the work done during the drilling and testing of this well initially.